# SOIL

in

# RURAL DEVELOPMENT

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# SOIL IN RURAL DEVELOPMENT

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THE TEXT OF THIS PAMPHLET HAS
BEEN PREPARED BY DR. H. L. UPPAL

CHAPTER I

# INTRODUCTION

ALONG with water and air, soil is essential for the maintenance of life. Nature has been very generous in its gift of soil to mankind, and it is only its unintelligent use that has withheld prosperity from the masses.

It is a well-known fact that fruit and crops grow on soil. Little is, however, known about the other qualities of soil which enable us to build roads and houses. A proper understanding of soil can be of great value in building fairly stable houses, roads, embankments, dams, and air fields.

India's rural development is slow because the conventional material for building roads and houses is scarce. Since this material has to be carried to the site of construction over long distances, it is usually uneconomical to use.

Rural development would be speeded up considerably if the soil available locally could be used for construction work. This should not be difficult. In India, the construction of both roads and houses has been carried out successfully in recent years.

The type of soil used for construction purposes is distinct from agricultural soil. The latter should be loose in texture and should allow air and water to percolate through whereas, for construction purposes, soil should be as compact as possible, and allow the least amount of permeability.

The object of this note is to tell the reader, as simbly as possible, how the best use can be made of soil in building houses and roads.

CHAPTER II

# PHYSICAL PROPERTIES OF SOIL

Soil is the weathered crust of the earth which extends to a few feet below the surface. The depth of soil varies from place to place and depends upon the mode of its formation.

## PHYSICAL COMPOSITION

Physically, soil has three main constituents, namely, sand, silt and clay. Of these, sand is the coarsest fraction. Silt is somewhat finer than sand, and clay is the finest. Sand serves as a structural material, silt as a filler and clay as a binder. The particle of each is different in size from the other. Apart from this difference, sand and silt are inert materials whereas the clay particle is active. It is .002 mm in diameter. The finer the clay, the more active it is. The fact that a depth of 10 feet of muddy water in a well will take about 10 years to clear up if left undisturbed is an indication of the fineness of the clay particle.

## EFFECT OF ITS CONSTITUENTS ON THE BEHAVIOUR OF SOIL

One often comes across lengths of kachha road which are very loose and have poor riding surface when dry, but improve slightly with a shower of rain. These lengths consist of soil which is predominantly rich in sand and, therefore, has little cohesion.

On the other hand, there are lengths of kachha road which are very hard and can weather fairly heavy traffic

when dry, but which become muddy with a little rain and are rendered unfit even for light traffic. Such roads have soil that is rich in clay.

There are roads which behave poorly under traffic all the year round and have soil that contains silt in large quantities. There is yet another type of length which behaves reasonably well under traffic all the year round. Such lengths are made of soil in which its various ingredients exist in more or less equal proportions.

It is thus evident that any one ingredient, when present in excess of the others, can make soil unfit for conveying traffic during both dry and wet seasons. It is, therefore, very important that soil should be well graded. If the soil contains a coarse aggregate, as generally happens in hilly areas, it is essential that it should be properly graded. The quantities of the various fractions should be such that voids created by the bigger particles are filled in by smaller particles in the other fractions, and so on.

### HOW GRADING CAN BE ACHIEVED

Soil predominant in sand can be put to good use if it is mixed with soil which is rich in clay. The properties of the resultant mixture are directly related to the ratio in which the two soils are mixed together. Though there are apparently no clayey soils in alluvial plains, yet, with a little effort, a clayey soil can easily be located either on the surface or a foot or so below it.

Sometimes it is difficult to find sand or sandy soil in areas where there are thick clay deposits. In such cases, the clay fraction of the soil can be partly nullified with some of the chemicals or waste products of industries. The percentage of the sand, silt and clay content of the more important Indian soils are given in the table below. The proportions of its constituents will give an idea of the

behaviour of soil during wet and dry seasons :

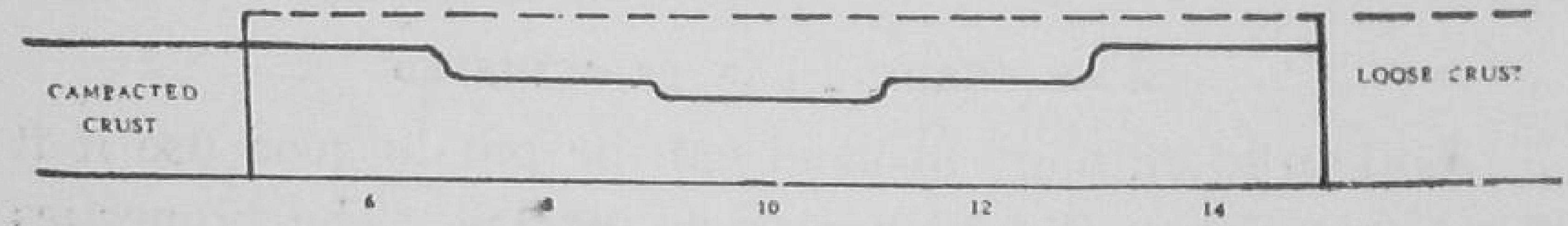
| | Coarse aggregate | Sand | Silt | Clay |
|---|---|---|---|---|
| Sandy loam | Nil | 60-70 | 30-40 | 8-10 |
| Loam | Nil | 45-50 | 30-35 | 10-15 |
| Silty clay loam | Nil | 25-30 | 60-70 | 15-20 |
| Black cotton soil | Nil | 5-7 | 20-25 | 60-70 |
| Moorum | 30-35 | 20-25 | 10-15 | 20-25 |
| Laterite | 80-85 | 5-10 | 3-5 | 2-3 |

COMPACTION OF SOILS

A loose soil, however well graded it may be, cannot take load without undergoing considerable deformation. Soil must, therefore, be compacted before it can bear load. During compaction, the soil particles are forced together and become tightly packed. This is brought about by moisture which largely determines the degree of compaction. The effect of moisture during compaction has been explained in the following illustration. (Fig. I).

**FIG. I**

**EFFECT OF MOISTURE ON THE COMPACTION OF SOILS**

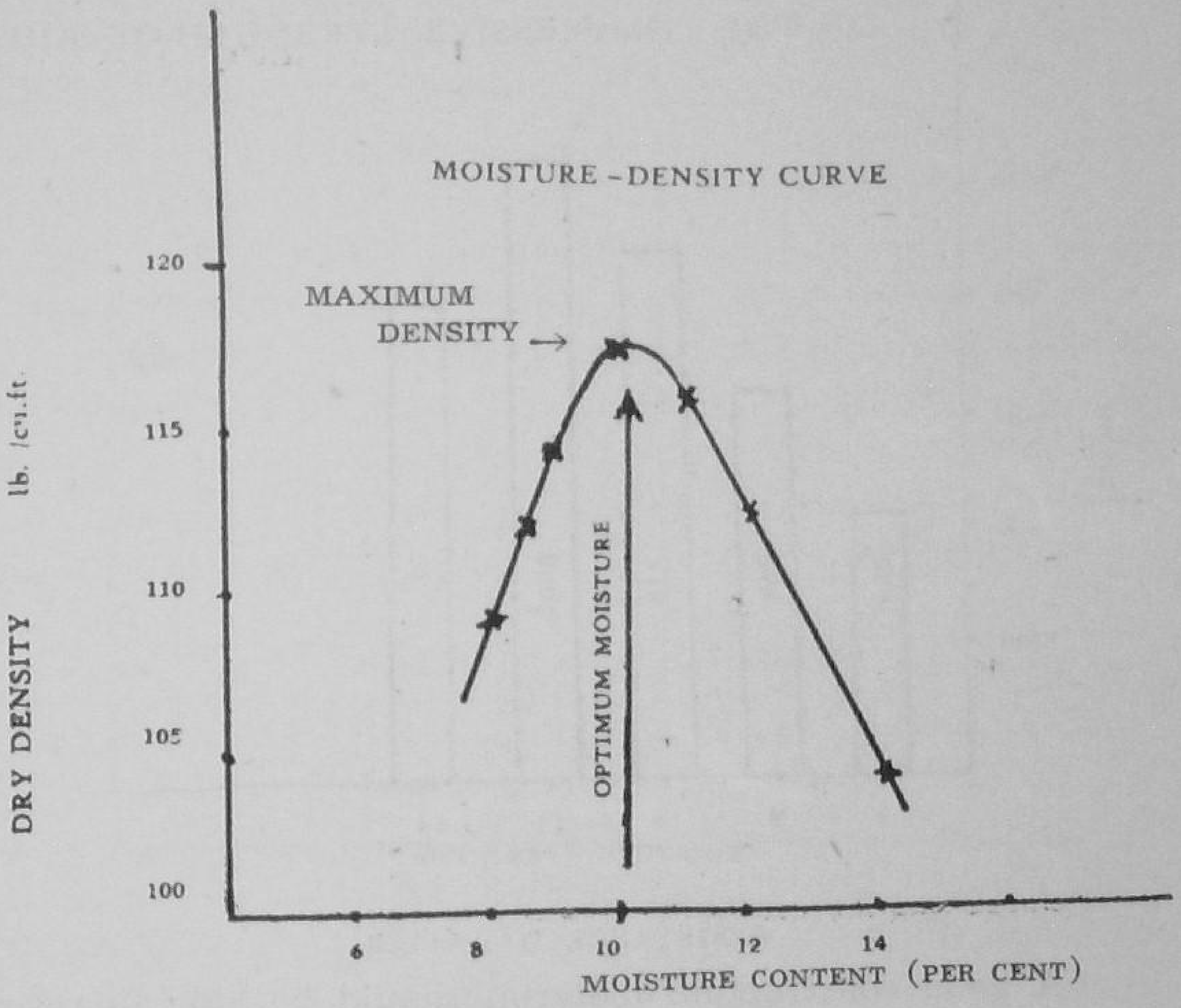



If loose soil is laid on the road about six inches thick, and a road roller passed over it a number of times, the resultant thickness of the compacted crust will vary according to the degree of moisture present in the soil at different points.

It is obvious, therefore, that there must be a particular degree of moisture that affords maximum compaction. This degree is called the optimum moisture. The optimum moisture varies from soil to soil and also depends on the force applied during compaction. If a heavy mode of compaction is used, the optimum moisture is low. This holds good for both the manual and the mechanical mode of compaction.

The degree of compaction is generally measured by the density attained as a result of compaction and is expressed as the weight of dry soil per cubic foot. The effect of moisture on the compaction of soil has been scientifically illustrated in Fig. 2.

FIG. 2




The two main essentials of a construction material are,

(i) high compressive strength and

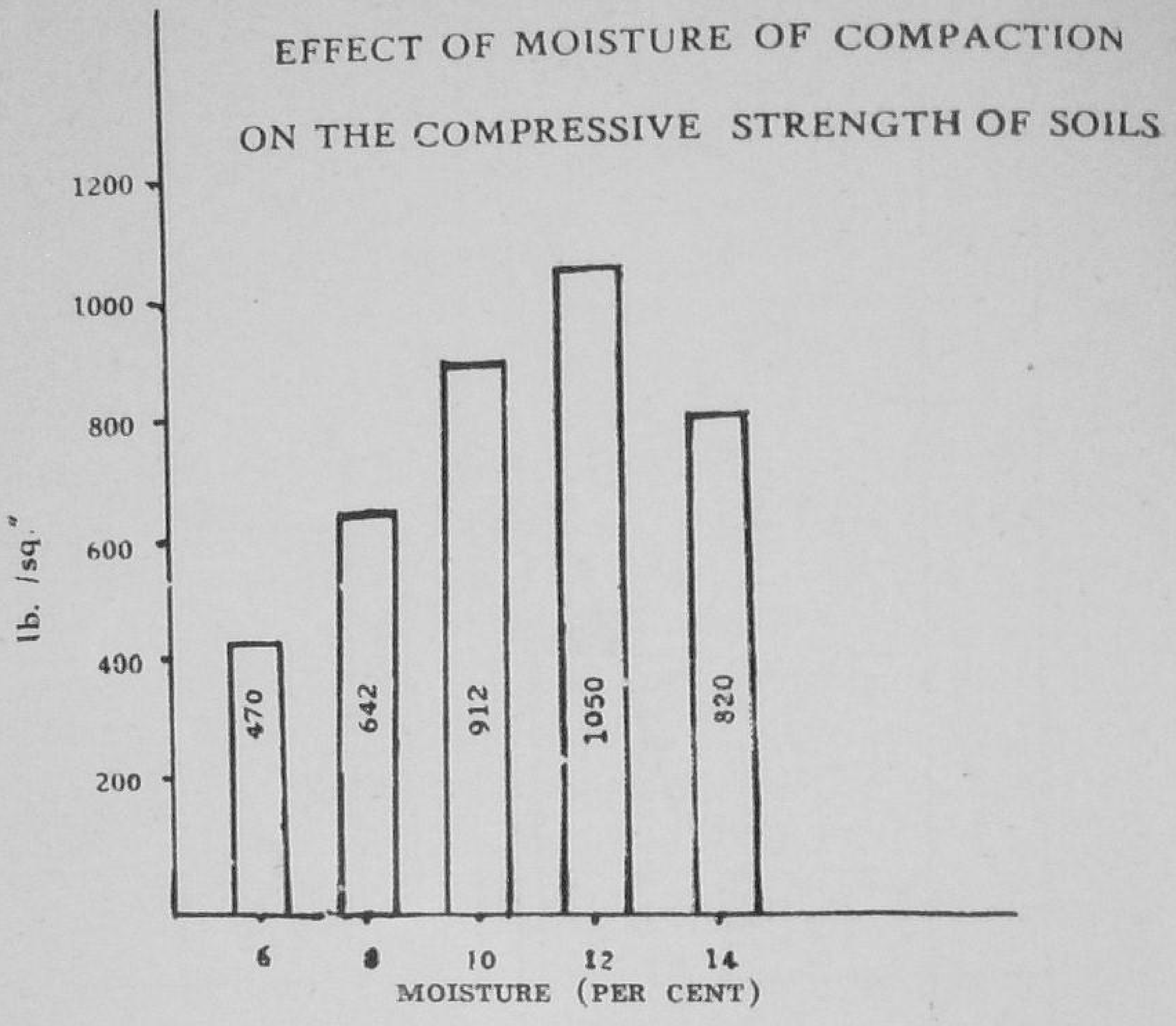
(ii) high resistance to the softening action of water.

COMPRESSIVE STRENGTH

When the blocks made by compacting soil at points of different moisture-content are subjected to a compression test, the order of the compressive strength is the same as

the moisture-density relationship. (Fig. 3). Thus, by compacting the soil at optimum moisture, the highest compressive strength for the soil is attained.

**FIG. 3**



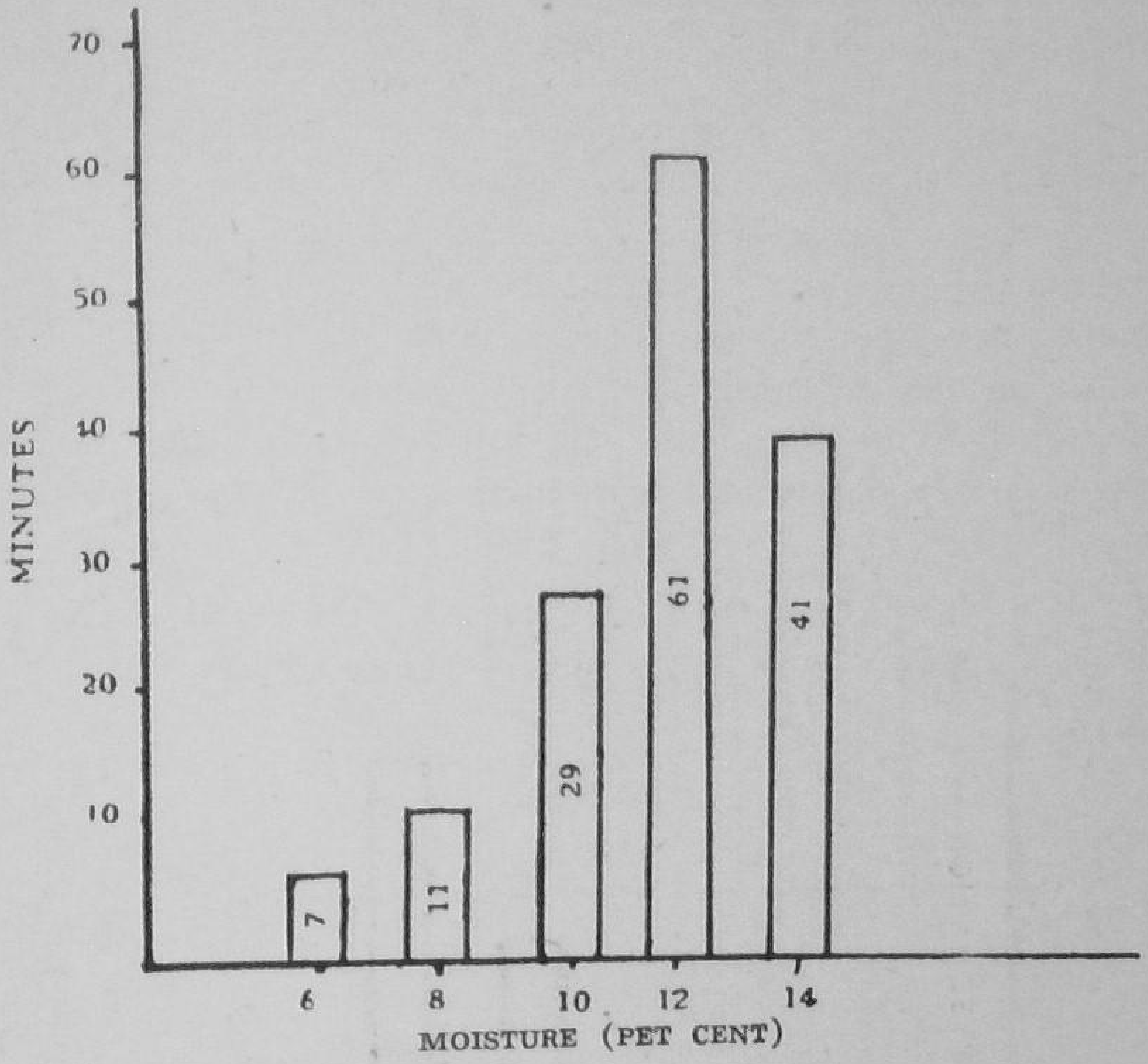

### RESISTANCE TO WATER

A good construction material should be able to resist the action of water. If blocks made by compacting soil at points of different moisture content are immersed in water, the behaviour of the blocks is directly related to the moisture-density relationship curve. A Soil which is compacted at optimum moisture offers the maximum resistance to water. (Fig. 4).

A soil which is improved by grading or by some other method and subsequently compacted is said to be stabilized.

FIG. 4

EFFECT OF MOISTURE OF COMPACTION
ON THE
DISINTEGRATION OF SOILS




USE OF BINDERS IN SOIL STABILIZATION

The resistance of soil compacted at optimum moisture is much greater than that of one compacted at other degrees of moisture. Even so, the resistance of the former is, on the whole, much lower than that required in construction materials.

The resistance of compacted soil to water can be increased by either coating the rammed soil with a waterproof plaster or by adding some water-proofing material to the soil during compaction. Some of the common binding

materials that can be economically used stabilized soil works are,

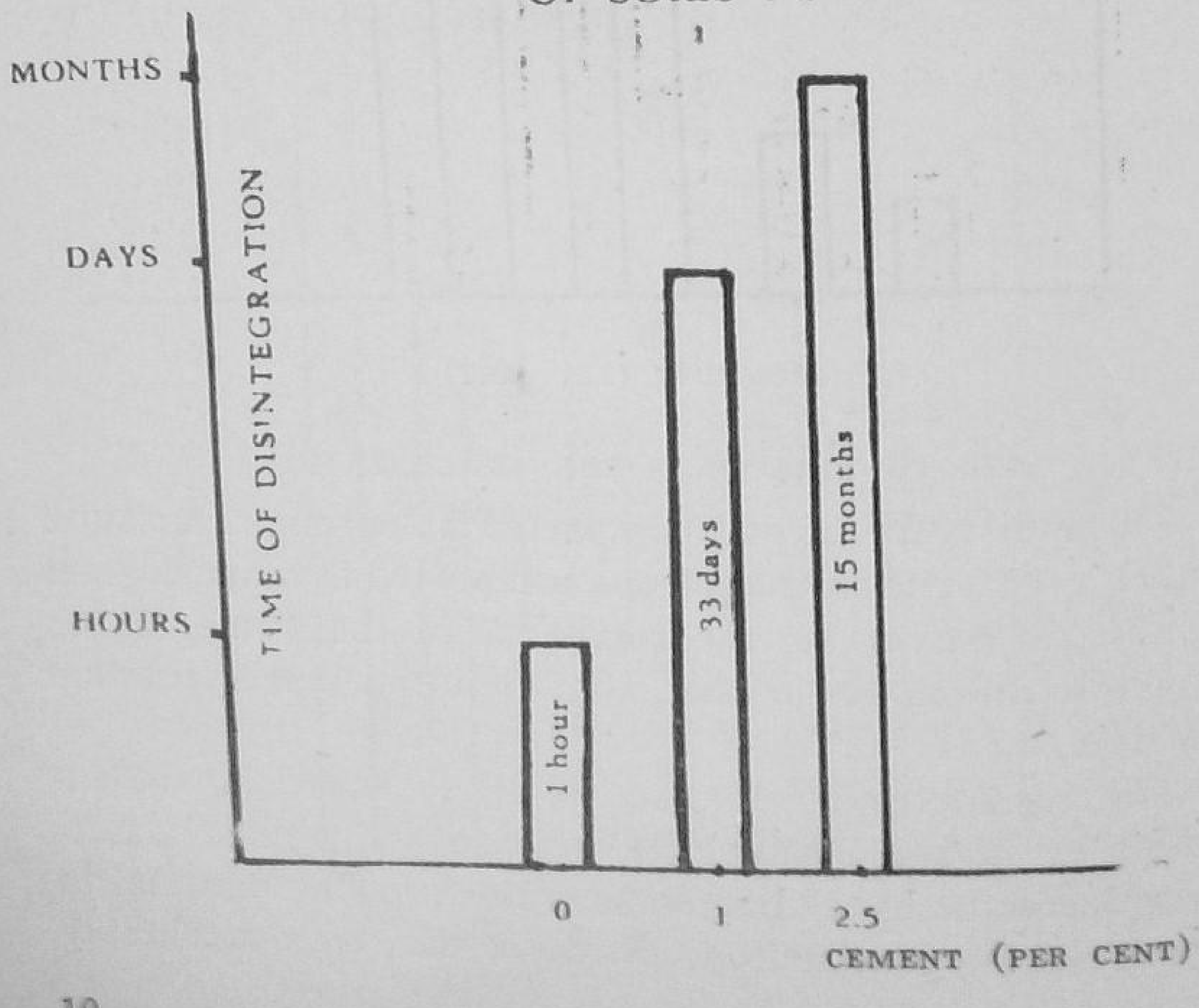
1. bitumenous binders
2. binders insoluble in water, and
3. binders soluble in water.

### THE BITUMENOUS BINDER

This consists of bitumen and can be used in various ways. The bitumenous material can be mixed with soil and used as a plaster on a compacted, dry wall. This prevents the moisture from travelling to the interior which remains dry and consequently retains its strength. The binder can also be mixed with wet soil in quantities varying from 5 to 10 per cent. The mixture thus prepared is allowed to dry partly and then compacted. The compacted

**FIG. 5**

EFFECT OF CEMENT ON THE RESISTANCE OF SOILS TO WATER

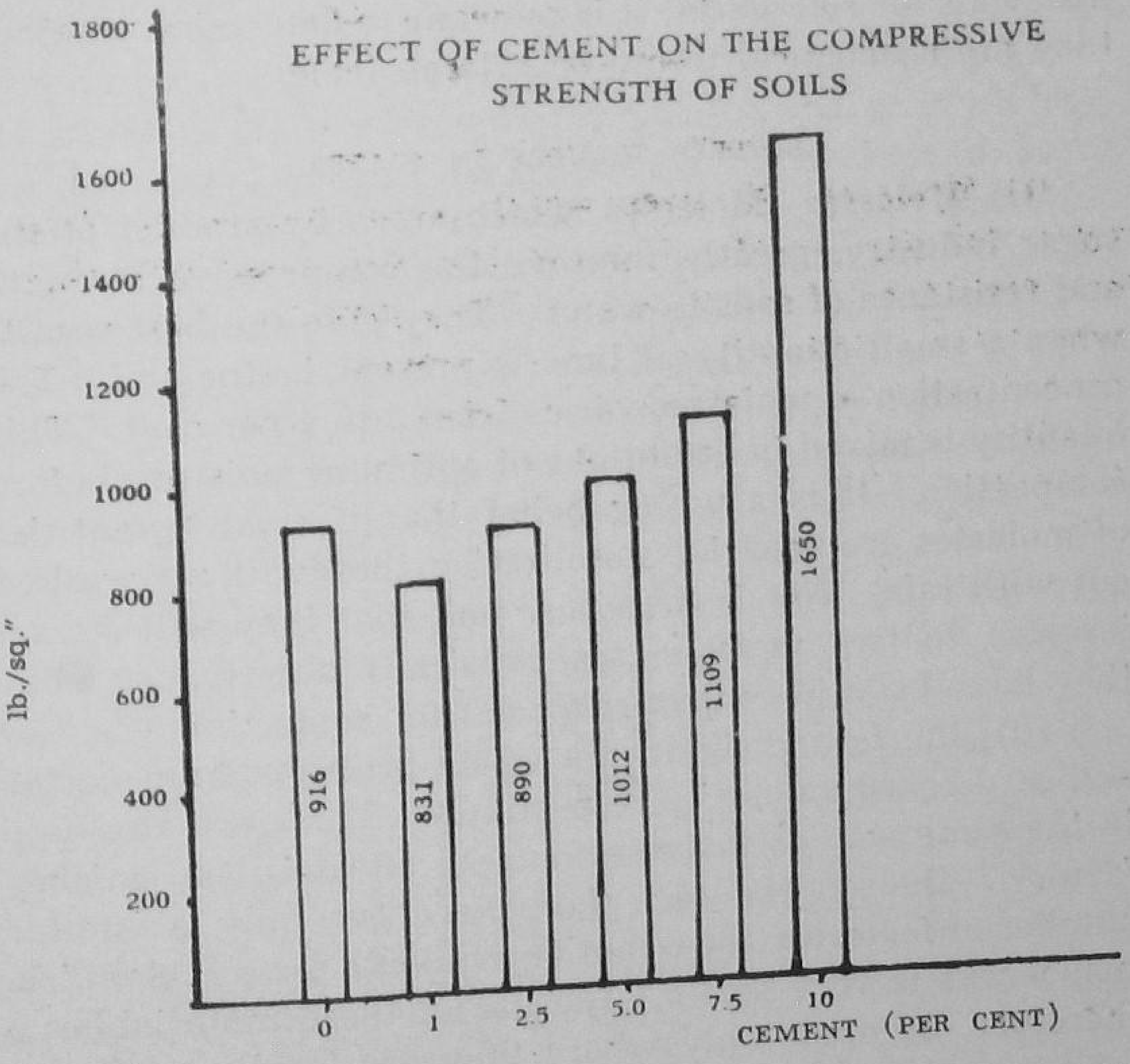


mass is wholly resistant to water. It has been observed that sandy soils do not give encouraging results on account of the fact that they do not have much cohesion.

### BINDERS INSOLUBLE IN WATER

(i) *Cement*—Cement has been found to be very successful in imparting resistance against water to soil. A soil block, which would disappear in a couple of minutes when immersed in water, will remain unaffected for more Cement can be mixed with soil at optimum moisture and used within 20 minutes of mixing so that it may not set. than a year if it is compacted with 3-5 per cent cement. The addition of cement not only increases its resistance to water but also the compressive strength of soil. (Fig. 5 and 6).

**FIG. 6**



The concentration of cement to be added will depend upon the resistance to water and the strength required of the mixture.

(ii) *Lime*—Clayey soils are unsuitable for construction purposes because of their tendency towards high shrinkage and loss of stability in wet conditions. Such soils can be greatly improved with lime. The concentration of lime required will vary from 5 to 10 per cent and will depend upon the percentage of clay in the soil. Lime can be mixed with soil and then compacted at optimum moisture.

(iii) *Tamarind seeds and oil seed cakes*—These two materials have also given good results in laboratory tests for certain types of soils but no successful field scale trials have been reported. In considering the use of these materials for soil works, it is relevant to determine whether they are economical to use on a large scale.

## BINDERS SOLUBLE IN WATER

(i) *Molasses*—Molasses, which are a by-product of the sugar industry, greatly improve the compressive strength and resistance of soils to water. They give the best results when a small quantity of lime is present in the soil. The concentration of molasses varies from 3 to 4 per cent. This quantity is mixed in conditions of optimum moisture before compaction. It is a wrong belief that if small quantities of molasses are used for stabilization they will get washed out with rain. Nor is there any fear that they will attract insects. In fact, molasses are physically almost lost when they have been in contact with soil for some time.

(ii) Jhuria and lignin are waste products from *kattha* and card board industries respectively. These are also used in the same way as molasses but the effect is less satisfac-factory. Due to the fact that there are only a limited number of factories, the quantity available for soil stabilization works is very small. The use of these materials can, therefore, be made only where they are locally available.

CHAPTER III

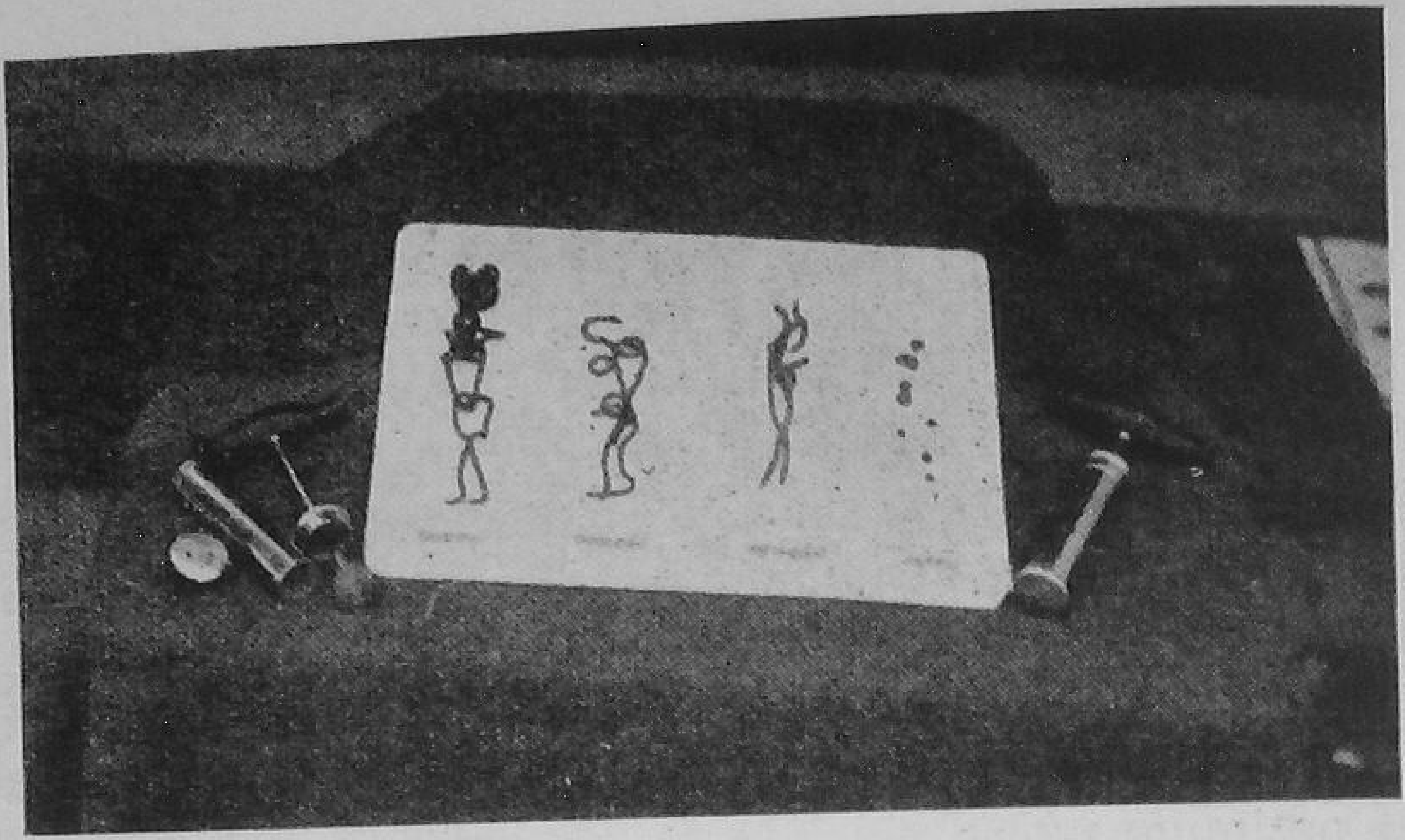
# SOIL CONSTRUCTION

THE soil, as already mentioned, should be well graded and compacted at optimum moisture if good results are desired. The tests generally used for determining the method of grading and the correct moisture of compaction are those of (i) plasticity index, (ii) sand content, and (iii) optimum moisture.

Soil can exist in several states when mixed with water in different proportions. When the state of the soil is such that with slight jarring it begins to flow, the moisture percentage is said to be at the liquid limit. On the other hand, when the moisture of the soil is so low that it crumbles if rolled finer than a thread ⅛″ thick, it is said to be at the plastic limit. The difference between the two states of moisture, namely, the liquid limit and the plastic limit is called the plasticity index and is expressed numerically. It is an indication of the sandy or clayey character of the soil. The higher the clay content, the higher the plasticity index will be.

The standard method of determining the plasticity index is fairly lengthy and may not be helpful in rough field work where a number of soil samples are sometimes tested and found unsuitable. For the determination of the approximate plasticity index of soils, a mechanical device has been evolved. This consists of a syringe having a tube six inches long and one inch in diameter. To one end of the tube is fixed a cap with 2 or 3 holes and about ⅛″ in diameter. A piston rod passes through a cap at the other end of the syringe. (Fig. 7).

FIG. 7



The plasticity index is determined by taking a small quantity of soil and kneading it with water in the form of a ball. The wet soil is put into the tube by removing the front cap which is fitted back again. By applying force from the other end, the wet soil is extruded in the form of threads. The state of the smoothness of the surface of the thread gives a rough idea of the plasticity index of the soil.

Soils, with a plasticity index of less than seven give disjointed threads with uneven surface due to the predominance of sand, while those with an index of more than 11 give very smooth and regular threads owing to the excess of clay. On the other hand, soils, the plasticity index of which lies between 7 and 11, give regular threads with surfaces of varying smoothness.

SAND CONTENT

For field work, sand content can be considered to be that fraction of the soil which can pass through a 36 B.S. sieve and retained on a 200 mesh sieve.

The standard procedure is to powder the soil in a wooden pestle and mortar and then to pass it through the two above mentioned sieves. Passing the soil through a

36 mesh sieve is fairly easy, but it takes a long time to powder the sample repeatedly till all the fine material can pass through a 200 mesh sieve. The method has been simplified by resorting to wet sieving. This is described in brief below.

A known weight of the soil, say 10 gm., is taken in a beaker. Tap water is added and the suspension well stirred. It is then passed through a 36 B.S. sieve. All the soil passes through in one lot. The filterate is allowed to stand undisturbed and the supernatant liquid is passed through a 200 mesh sieve. The residue in the beaker is rubbed gently with a finger fitted with a rubber tip, and more water is added till the clay goes in suspension. After allowing a minute or so for the sand to settle, the suspension is passed through a 200 mesh sieve. The process is repeated till the suspension is clear after standing for a minute. The sand is transferred to a 200 mesh sieve, washed 2 to 3 times with water and then transferred to a porcelain dish. It is then mixed with a little alcohol and burnt. The weight of the dry sand is determined to find out the percentage.

## OPTIMUM MOISTURE

After the grading has been done and the soil of the required specifications collected, it is necessary to compact it at optimum moisture to attain maximum density and make it suitable for construction purposes.

In order to determine the optimum moisture in the field, a measured quantity of water is added to a small volume of soil and well mixed with it. A little of this soil is then pressed in the shape of a ball. If it does not bind well, another known quantity of water is added and the soil tested again. If the soil binds well and neither sticks to the hand nor wets it, it is at optimum moisture. The value of optimum moisture thus obtained is used in actual construction.

As there is always some initial moisture the optimum must be determined by the above method.

CHAPTER IV

# STABILIZED SOIL IN BUILDING CONSTRUCTION

THE material selected for building construction should have the following qualities :

1. High compressive strength,
2. resistance to softening under water, and
3. high insulation.

*Compressive strength*

A gradded soil, when compacted at optimum moisture, compares well in strength with a burnt brick. It can, therefore, replace burnt brick so far as compressive strength is concerned. It will not be out of place to mention that green bricks, which are neither graded nor compacted at optimum moisture, are very poor in compressive strength and should, therefore, be used only for a temporary and very inferior type of structure.

*Resistance to Water*

Soil compacted at optimum moisture has a fair amount of resistance to water and can safely be used in dry areas. If, however, it is intended to be used in areas of high rainfall, the soil all should be given a thin coat of waterproof plaster consisting of soil, bitumen and straw. The waterproof coat will check the penetration of moisture and maintain high compressive strength in the wall.

High resistance to water can be imparted to soil by compacting it with small quantities of cement. In such

cases, the wall can take up a cement-sand plaster effectively and also present a neat finish.

*High insulation*

It is of the utmost importance that the material used for building construction in tropical countries should give a fair amount of protection against heat. The insulation provided by graded and compacted soil is superior to that of burnt brick or cement concrete. It has been found that a thickness of 15″ gives a wall reasonably good insulation against heat in summer. The corresponding thickness of burnt brick and cement concrete needed to give the same insulation is 26″ and 33″ respectively.

*Construction*

Field construction can be of two types, namely, brick construction and monolithic structure.

*Brick structure*

To start with, the proper type of soil should be located by the laboratory. This can be done by the methods described in Chapter III. The soil can then be collected and compacted into moulds at optimum moisture. A suitable size should be selected for the mould so that the brick is not too heavy to carry. 15″×10″×5″ is a fairly good size and the brick weighs about 40 lb. The brick can be laid in clay-soil mortar and plastered if necessary. In case the construction is being carried out in areas of high rainfall, a certain quantity of cement can be mixed with the soil. These bricks can then be laid in 1:8 cement-sand mortar.

The compaction can be carried out either manually or by mechanical means. The mechanical method gives uniform, well compacted and nicely finished bricks and should, therefore, be given preference to manual compaction. The advantage of brick construction is that bricks can be

made at leisure by the village family themselves and stored. The construction can be undertaken whenever it is convenient.

*Monolithic Structure*

This involves compacting soil between planks which are fixed apart, the distance between them depending upon the thickness desired for the wall. A shuttering 3 feet high that corresponds to the four walls is built all round. When the compaction is complete, the entire shuttering is raised to carry the compaction to the next 3 feet. This type of construction is quicker, more sound and economical because the extra charges for carrying the blocks and laying them in the wall are eliminated. Of course, it has one disadvantage, namely, that it cannot be done without co-operative effort, both in cost and construcion and cannot be undertaken by an individual at his leisure as in the case of a brick structure. The design of the shuttering has also to be perfected in order that it may be light and easy to handle.

Since this type of construction requires shuttering and some skilled labour, it cannot be worthwhile unless about 25 houses are to be constructed. If the villagers pool their labour and resources, the cost can be reduced considerably.

## THE ROOF

The construction of the roof will depend upon the material available at the site. It may either be in thatch or in tile and batten, depending upon the amount that can be spent.

CHAPTER V

# OTHER USES OF SOIL IN THE VILLAGE

### DRAINAGE

More important than the house itself is a proper drainage system. Soil can be compacted *in situ* with a mould of convenient length. If need be, the base of the drain can be hardened by adding cement during compaction. When stabilized with bituminous material, it will be an effective check on permeability.

### FLOORS

The floors of the cow sheds can be kept from getting muddy if the soil used is properly compacted with brickbats and *kankar*. It can be improved further if a binder is mixed with the soil.

### PONDS

Since the supply of water in the villages is uncertain, it is necessary to make provision for storing water. To store water all the year round, the beds of the ponds can be made impervious. This can be achieved by compacting soil in layers after it has been mixed with a binder. The choice of the binder will, however, depend upon the nature of the soil. Stabilization of soil can also be used to check erosion, to build embankments and to reduce the seepage of irrigation channels.

CHAPTER VI

# LOW COST ROAD CONSTRUCTION

WHILE a road connects a village with neighbouring towns and markets, it also brings with it facilities for education and public health and, therefore, should be given great importance. All attempts to grow more food will be of little use unless there is a proper road to take the produce out of the village.

From the point of view of construction, there are two types of road :

(1) bituminous and (2) concrete. The bitumious road costs about Rs. 30,000 to Rs. 35,000 and the concrete one about Rs. 50,000 per mile, the width of the road being 10 ft. in each case.

The roads constructed by either of the above systems can carry heavier traffic than is required to be carried from the villages. There is, however, no alternative system of road construction which is cheaper. It means, therefore, that we have either to build roads at exorbitant cost or go without them. The cost of consructing roads is heavy because burnt brick, stone and tar have to be carried to the building site from long distances.

Generally speaking, roads are constructed in three different stages. The first is the subgrade stage. The road is laid on the natural surface of the earth. The surface is compacted with a flat roller before the next layer is put on. The second stage is the base course, in which burnt bricks are laid either flat or edge-wise on the compacted surface. Finally, there is the wearing surface stage, which consists in laying stone metal on the bricks and rolling it

flat to a thickness of 4″ to 8″. The surface is then cleaned and covered ith tar and stone chips to seal the road surface against water, and to create abrasive resistance.

### USE OF STABILIZED SOIL

As stated earlier, a properly graded soil, compacted at optimum moisture, gives material which compares well in strength to burnt brick. Since brick is used in the conventional type of tar road only for strength, it should be possible to replace bricks with compacted soil. This will result in a saving of about Rs. 5,000.

Replacing bricks with soil in a tar road, however, still does not make the cost of construction less prohibitive for a village. Therefore, the solution lies in using soil in all the stages of road construction. A village road generally takes only 50 to 100 tons of trajc per day and, therefore the specifications need not be very costly. As a result of various trials in the Punjab, the following specifications have been found to be satisfactory for building roads at lost cost.

The *subgrade* is prepared by rolling the existing earth surface with a flat roller.

4½″ of loam soil at optimum moisture is rolled down to 3″ with the help of a flat roller for the base course.

For the wearing course, a mixture of two parts of loam soil and one part of brickbats or *kankar* in a loose layer 5″ deep is rolled down at optimum moisture. The addition of some of coarse aggregate creates abrasive resistance in the crust. It has been observed that a soil with a plasticity index of 9-11 and a sand content of 35-50 gives the best results in areas with an annual rainfall of 20 to 35 inches.

*Behaviour*—The above type of road gives fairly satisfactory service throughout the year. During the dry season, roads constructed in this manner are almost free from dust when the traffic is slow but become slightly dusty when there is fast traffic, such as a bus service, for instance. Small ruts are formed by bullock carts but get ironed out by traffic

in course of time with the help of moisture. The utility of such roads should be assessed in the light of the fact that, during the rainy season, thousands of villages are cut off from neighbouring towns for want of any kind of road.

*Maintenance*—The stabilized soil roads can be maintained by the villagers themselves. Should pot-holes be formed due to traffic, they can be filled immediately with the soil used originally. The addition of a small quantity of molasses solution to the soil will give it greater endurance. The mixed soil can then be compacted with a hand-hammer. Even if the work has to be done on payment, one coolie per month will be able to repair 2 to 3 miles of road.

### TARRING THE STABILIZED SOIL SURFACE

The unsurfaced stabilized soil road can be used throughout the year when the rainfall is not heavy. If the road is tarred with stone chips and bituminous material, it will give service throughout the year. The tarred road will have the additional advantage of being dust free and will also be able to carry heavier load. The tarred surface can be given a new tar coat every third or fourth year, depending upon the nature and bulk of the traffic it carries.

CHAPTER VII

# THE ECONOMICS OF STABILIZED SOIL CONSTRUCTION

### BUILDINGS

It is claimed that a construction for which stabilized soil has been used is a permanent structure. It would, therefore, be logical to compare its cost with that of the burnt brick structure. Since the costs of roofing material and joinery vary considerably from place to place, an idea of the comparative cost can be had from the cost of the wall. In tropical countries, a wall constructed of burnt brick must be at least 13½″ thick if it is to provide adequate insulation. In the case of a wall constructed with soil, a thickness of only 9″ can give the same degree of insulation. The cost of walls in the following table has been compared on the above assumption, and calculated on the basis of voluntary labour :

| | Per 100 sq. ft. of wall | | |
|---|---|---|---|
| Stabilized soil wall *in situ* | 22 | 4 | (shuttering only) |
| When laid in 2.5 % cement | 36 | 18 | (cement and centering) |
| Burnt brick laid in mud | 56 | 45 | (exclusive of laying) |

It would appear from the above table that the stabilized soil wall can be constructed at almost half the cost on the basis of payment, and at one third the cost if the labour is voluntary. There is also a lot of saving in coal and fuel which can be utilized for other important work.

### ROAD CONSTRUCTION

The use of soil makes it a simple matter to build roads

when construction is otherwise held up for want of burnt brick, stone metal or tar. The cost of construction has been given in the following table to show the saving that can be achieved by using soil :

Per mile of road (10 ft. wide)

| | Hired labour | Voluntary labour |
|---|---|---|
| Water-bound, conventional type | Rs. 30,000 | Rs. 28,000 |
| Replacement of burnt brick in the base course of the above type of road .. | Rs. 26,000 | Rs. 23,000 |
| Stabilized soil road .. | Rs. 7,000 | Rs. 4,500 |
| Tarred road constructed from stabilized soil .. | Rs. 15,000 | Rs. 11,500 |

It would appear from the above table that a road to the village can be provided to give service all the year round at a cost of Rs. 7,000. The cost can be reduced to Rs. 4,500 when the construction is made by the villagers themselves.

The same road can be tarred to enable it to carry more load, make it free from dust and serviceable in areas of high rainfall at an additional cost of Rs. 7,000. This will mean roughly three times the length for the same cost.

It has been pointed out earlier that a well graded soil, when compacted at an optimum moisture, produces fairly strong material. In practice it may, however, not always be possible to get good soil because the nature of soil varies from place to place.

To cope with field work in various parts of the country effectively, it is essential that small units working in the villages should have regional advisers. The regional units should work under one central unit. The organization, on the whole, should be as simple as possible. While the work is in progress, a band of workers in the village can be trained for the maintenance of roads already built and for constructing them in the future.

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